Advanced Fuel Cycle Initiative
Semi-Annual Technical Review

- LBE Coolant Technology and International Cooperation

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Los Alamos National Laboratory

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Outline

- Synergy with Gen-IV LFR R&D and 5-Year R&D Plan
- Work Package Milestone Performance and Outlook
- Technical Achievements Highlight
- International Cooperation
- Conclusion

Transmutation by Lead/LBE-Cooled Fast Systems (ADS or Reactors) under Study for AFCI and Gen IV

- AFCI 5-Year R&D Plan

System	Neutron Spectrum	Coolant	Potential for Minor Actinide Transmutation
Generation-IV Reactor Type			
Gas-cooled Fast Reactor	Fast	Helium	High
Lead-cooled Fast Reactor	Fast	Lead or Lead Bismuth Eutectic	Medium to High
Molten Salt Reactor	Thermal (high intensity)	High temperature molten salt	Medium
Sodium-cooled Fast Reactor (high conversion)	Fast	Sodium	Medium to High
SuperCritical Water-cooled Reactor	Thermal	High Pressure (super critical) Water	Low
Very High Temperature Reactor	Epi-thermal	Helium	Medium

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Synergy with Gen-IV LFR Materials R&D

- Gen-IV Lead-cooled Fast Reactor (LFR) R&D (Roadmap)
  - "The options in the LFR class may provide a time-phased development path: The nearer-term options focus on electricity production and rely on more easily developed fuel, clad, and coolant combinations and their associated fuel recycle and refabrication technologies."
  - Similar baseline coolant technology

Reactor Parameters	Reference Value			
	Pb-Bi Battery (nearer-term)	Pb-Bi Module (nearer-term)	Pb Large (nearer-term)	Pb Battery (far-term)
Coolant	Pb-Bi	Pb-Bi	Pb	Pb
Outlet Temperature (°C)	~550	~550	~550	750–800

  - "***LFR Fuels and Materials R&D***
    - The material screening R&D will take the majority of the viability R&D time period and will require corrosion loops, posttest examination equipment, properties testing apparatus, phase diagram development, coolant chemistry control R&D,…"
  - "***LFR Reactor Systems R&D***
    - **Chemistry Control**. Viability R&D is also needed for chemistry and activation control of the coolant and corrosion products. Means for oxygen control are needed for both Pb and Pb-Bi options. ...
    - **Thermal hydraulics**. …"

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5-Year Coolant Technology R&D Plan

- Supports Critical Reactor and Accelerator-Driven System Technology Choice

- Define LBE technology envelope in non-irradiated environment
  - FY03: Completion of DELTA Loop 1000-hr corrosion test
  - FY05: Completion of oxygen sensor development
  - FY05: Issue LBE handbook without irradiation (under the OECD LBE working group)
  - FY06: Completion of long term corrosion test (up to 6000 hrs)
- Define LBE technology envelope with irradiation (to commence in FY05)
  - FY07: Issue LBE handbook to include preliminary irradiation data (under the OECD LBE working group)
- FY07: Issue report on LBE systems and materials performance limits

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Milestone Performance in 2nd-4th Quarters, FY02 and 1st Quarter, FY03

Milestones	M/S Level	Baseline	Status
Receive oxygen sensors for unattended operations	3	4/11/02	Ahead of schedule (under continued improvement)
Issue oxygen control and sensor calibration strategy report	3	5/31/02	On time
Complete operational tests including sensor calibrations	3	4/29/02	Completed later after improvement of experimental apparatus and procedures
Issue ultrasonic Doppler velocimetry report	4	8/30/02	On time
Issue revised DELTA Loop test plan	3	9/27/02	Ahead of time
Issue status report on low-T OS development	3	9/30/02	On time
Select test matrix for alt. OS materials and references	3	11/30/02	Completed

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Milestone Performance Outlook for 2nd-3rd Quarters, FY03

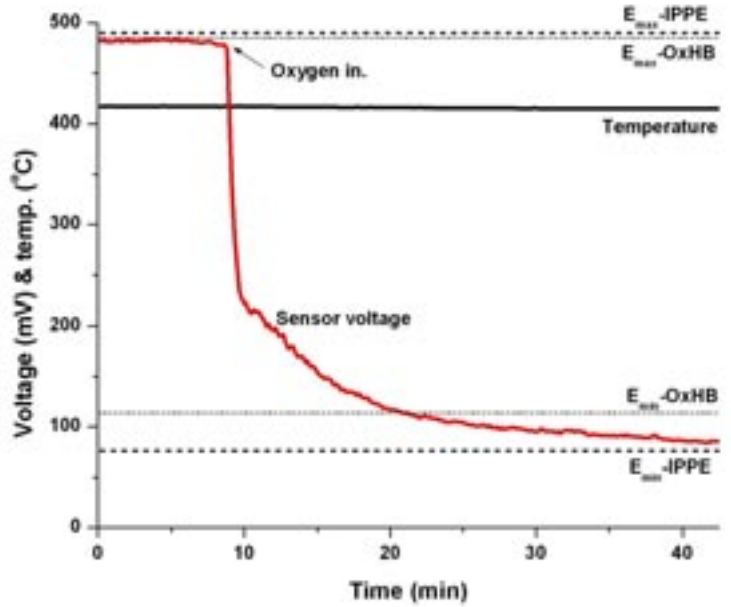
Milestones	M/S Level	Baseline	Outlook
Issue analysis report for irradiated oxide on 316L	3	1/03	On time
Deliver oxygen sensors to international partners	3	2/02	2 to KTH, the rest delayed – no exchange date planned by the partners, expect to complete with CEA by 6/02
First UDV measurement of LBE in DELTA	3	3/03	Delayed – DELTA loop test campaign delayed, expect to finish in 5/02
Summary of pre-conditioning oxidation parameters	3	4/03	On time
Initial analysis of corrosion test specimens	3	6/03	On time

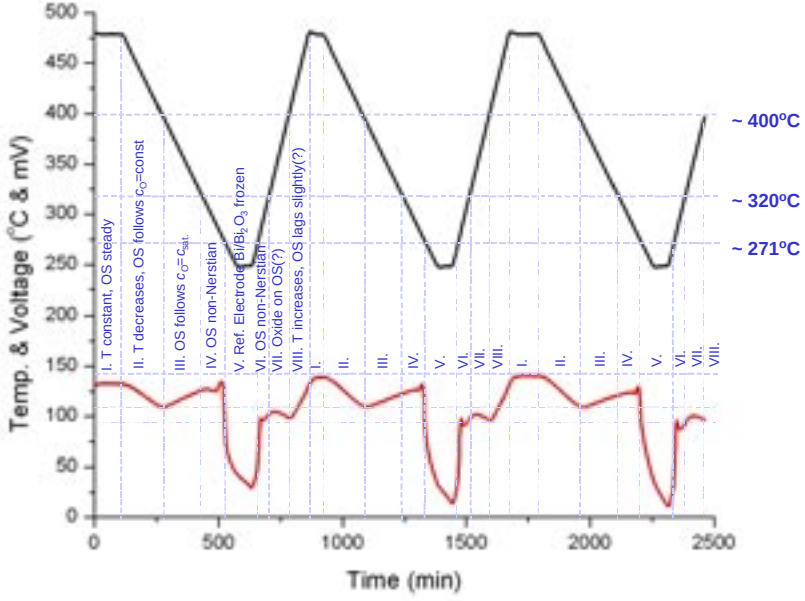
Technical Achievement Highlights

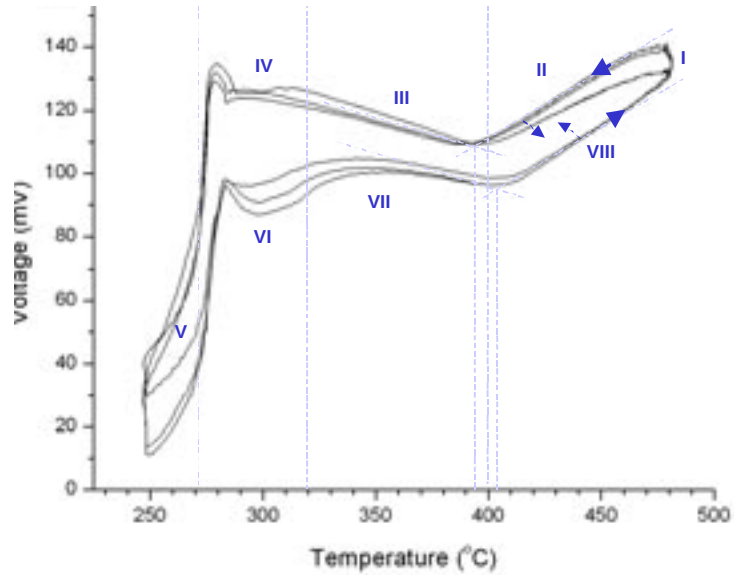
- Oxygen Sensor Dynamic Responses and Calibration (reports)
- Corrosion Model (reports/papers)
- TRAC Modeling of DELTA Loop (model/results)
- Adapting Ultrasonic Doppler Velocimetry to Measure LBE Flows (report)

Oxygen Sensor Dynamics Suitable for LBE

- Oxygen sensors have adequate dynamic range
- Dynamic behaviors and cycle lifetime are under study

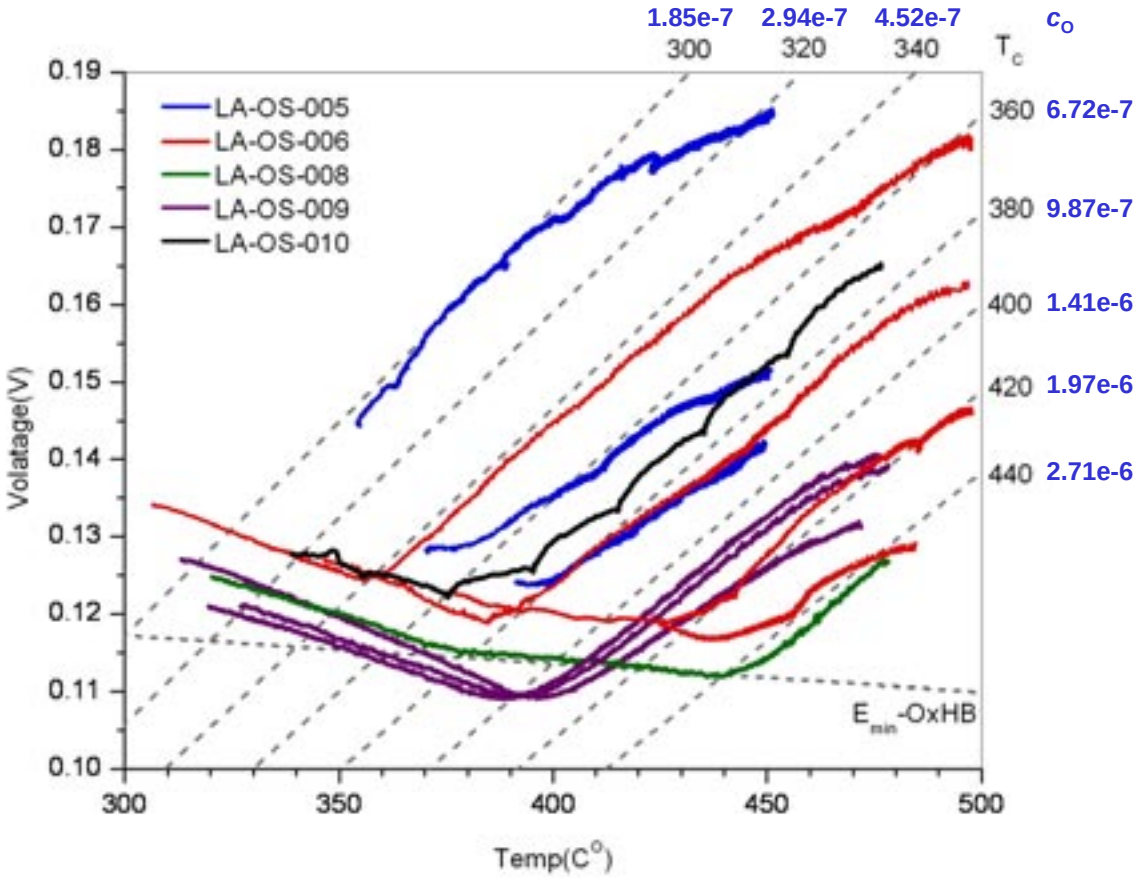






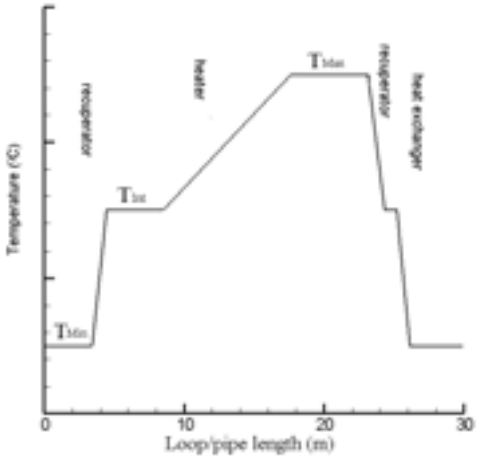
Calibrations of OS Confirm Nernstian Behaviors

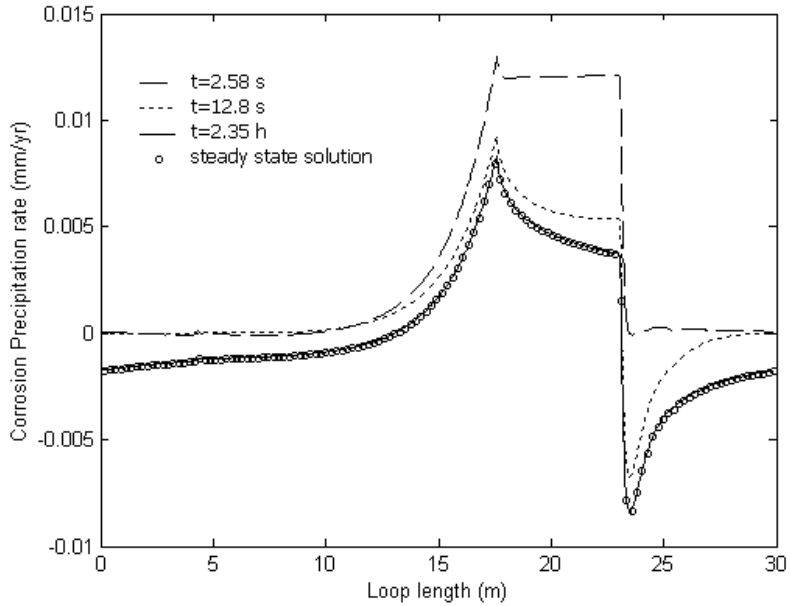
- "Fixed Point (Saturation)" approach used in calibration



Modeling Corrosion in Oxygen Controlled LBE

- Improved the application of local mass transfer models
- Expanded the kinetic model beyond simple loops to include multi-module loops and transient to steady state





Transient Fe corrosion/precipitation rate distribution for a simplified DELTA loop (T_{min}=350°C, T_{max}=550°C, T_{int}=450°C, c_O=0.01ppm)

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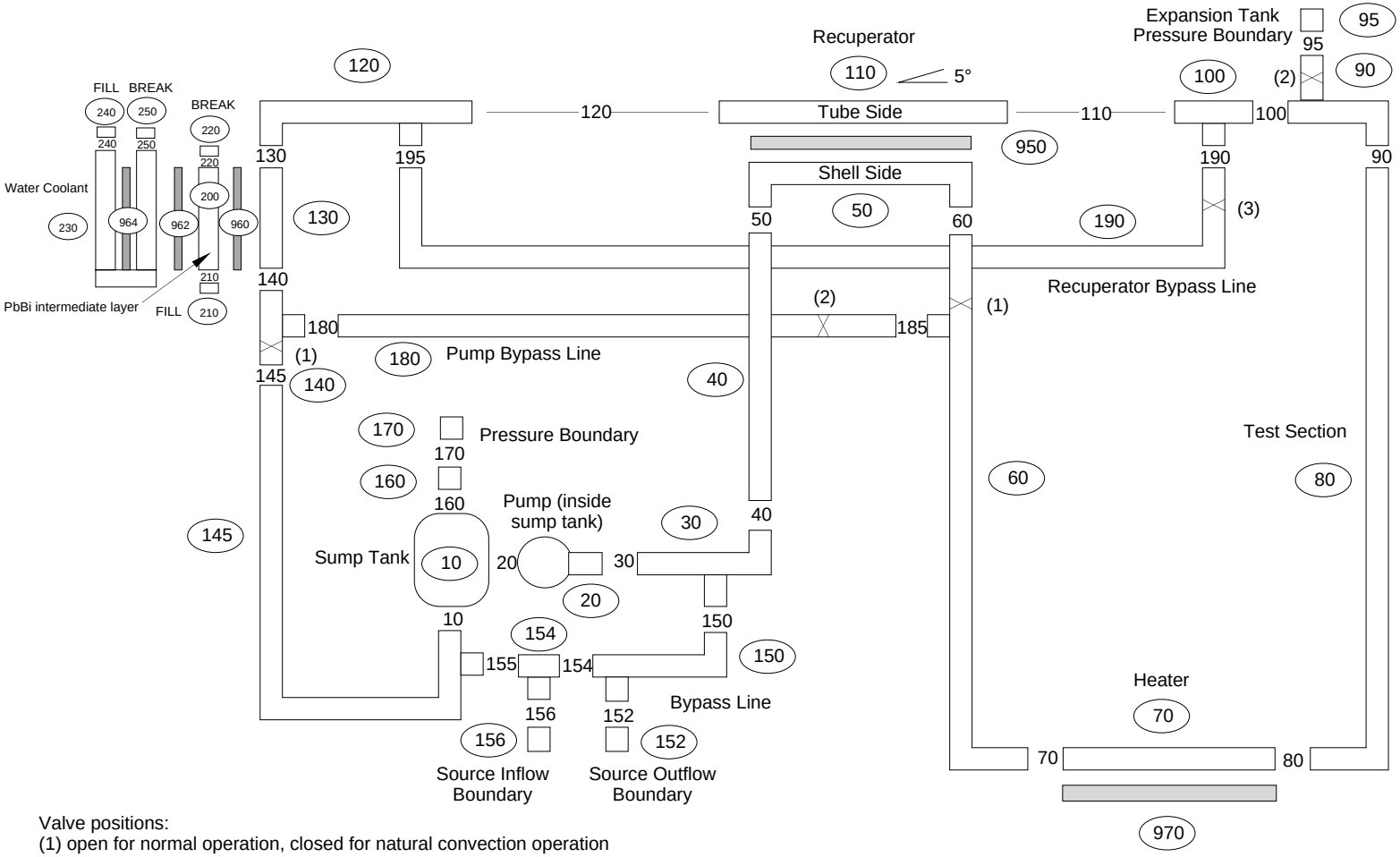
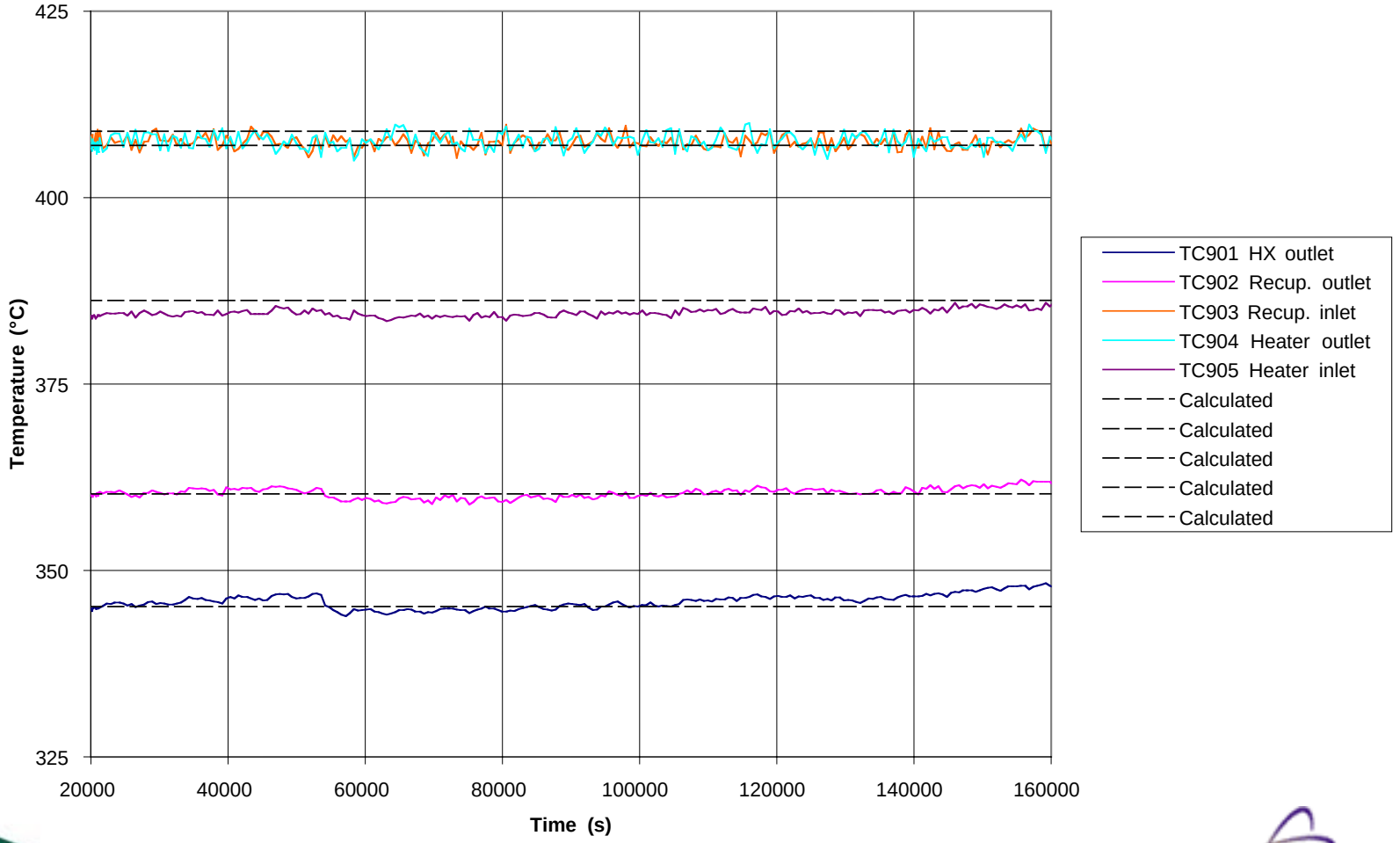
Near Complete TRAC Model of DELTA Loop



Valve positions:
(1) open for normal operation, closed for natural convection operation
(2) closed for normal operation, open for natural convection operation
(3) normally closed for both normal and natural convection operation but
can be opened to bypass recuperator for natural convection operation

TRAC Model Can Reproduce DELTA Operation Data

Comparison of test data to calculated results



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International Cooperation

- Russian LBE Test Loop delivered to UNLV
- DOE/CEA collaborations (Work Package 3) participation
- FZK Oxygen Control System(OCS) procured
- 2 oxygen sensors and calibration data delivered to KTH
- Exchanged reports with TECLA (EU) oxygen sensor group
- Recommendation of oxygen control for MEGAPIE to avoid liquid metal embrittlement; adapt TRAC to support MEGAPIE safety study
- 7 international groups toured DELTA Loop in FY02

Russian Target Delivered to UNLV for LBE Research

- Delivered in 5/02: Accelerometers indicated package sudden movement, pressure test found system gas tight
- International Molten Metal Target Advisory Committee met in UNLV in 8/02 and proposed test plans

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Supporting DOE/CEA Collaborations: WP3 LBE Technology

- Lead-Bismuth Loops and Corrosion Studies
  - LANL : Test plan of DELTA loop - Delivered, 12/01
  - CEA : Feedback and specific request for long-term tests - Discussed, 3/02
  - CEA : CICLAD test plan - Discussed, 3/02
  - CEA : report on coating technology and results - Not rec'd, discussed, 3/02
  - CEA : report on spallation product effects on corrosion - Not rec'd
  - Exchange of evaluation of Russian Corrosion Experiments - Done (papers and reports exchanged), results are consistent
  - LANL : review of test plan and comments - Discussed, 3/02
  - DRAFT joint test plan for corrosion experiments - Test conditions discussed and agreed to ("FY03 DELTA Loop Test Plan", first 1000 hr test temperature 500ºC, with 100ºC difference, 2m/s LBE velocity, 1e-6wt% oxygen, materials including T91, HT9, EP823, 316L and CEA aluminized 316L), 3/02
  - (MEGAPIE support work - see physics summary)

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Supporting DOE/CEA Collaborations: WP3 LBE Technology

- Oxygen Sensors
  - H2/H2O mixture technique for oxygen probe calibration
    - Benchmark development - The approach is agreed to, an apparatus can be available, current calibration uses fixed point (saturation) approach
    - Development of a methodology and test - A report is prepared ("Oxygen Control Methodology and Sensor Calibration Strategy")
      - Review of results and exchange of sensors - Dynamic calibration report is prepared ("Oxygen Sensor Calibration for LBE Coolant Chemistry Control"), no sensors exchanged yet (we can plan for such an exchange in the June meeting)
  - Effect of gamma field on oxygen sensor performance
    - Calculation of the gamma field and results comparison - Field level computed
  - Spallation Products Assessment
    - Analyse of Blue Room samples and discussion on follow-on work after review of the results - (see physics summary)
    - Send Russian Polonium extraction report - Delivered, 12/01

Supporting DOE/CEA Collaborations: WP3 LBE Technology

- Thermohydraulics
  - LANL : evaluation of the MEGAPIE hydrodynamic instability results and capabilities with specialized codes at LANL - Done, the large amplitude fluctuations in the original calculation are due to CFX code error, smaller fluctuation from an IPPE experiment may still impact fatigue performance ("Thermal Experiments in the ADS Target Model", in proceedings of FMTM2001)
- LBE purification technologies
  - Exchanges of documents - see report ("Oxygen Control Methodology and Sensor Calibration Strategy")

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Conclusions

- Coolant technology R&D plan is in place (AFCI 5yr R&D plan)
- Present and planned R&D tasks have strong synergy with Gen IV R&D for LFR
- Work package execution proceeds as planned
- We have extensive participation in international collaborations (DOE/CEA, UNLV/LANL/IPPE, LANL/FZK, MEGAPIE, OECD LBE Expert Group, DOE/JNC-JCC, etc)